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DP-303704

HEAT EXCHANGER TUBE

TECHNICAL FIELD

This invention relates to heat exchangers in general, and specifically to a novel construction for a fabricated heat exchanger tube.

BACKGROUND OF THE INVENTION

Cross flow automotive heat exchangers, such as radiators, condensers, and heater cores have, for decades, followed the same general design of a basic core bordered by two side tanks or header tanks. The basic core consists of a plurality of parallel flow tubes, stacked with brazed corrugated air fins between, the ends of which tubes are brazed leak tight into regularly spaced slots in the header tanks. The header tanks feed a flow medium into and out of the tubes, while air is blown across the tubes and air fins in a perpendicular or "cross" flow direction. Basic flow and heat transfer formula, also well known for decades, determine the optimum size of the flow tubes, as well, so that the biggest choice that a designer has to make is simply the best and most economical method of manufacturing the tubes. That choice, in turn, is partially driven by the method of assembling and manufacturing the core.

One of the two standard manufacturing methods for the tubes are the one piece extruded tube, in which a billet of hot metal, generally aluminum, is forced through a die that gives a constant cross section to the tube all along its length. Any part, produced in one, integral piece is generally thought to be more economical than a multi part piece, but, as noted, other considerations may apply. Extruded tubes have proven difficult to surface coat

with braze material. Consequently, the surface coating of braze material necessary to braze all parts of the core together must generally be applied to the corrugated fin material that contacts the outside of the extruded, one piece tube. Such braze material is abrasive and deleterious to the fin forming machinery, and the fin material must be made thicker and heavier than otherwise needed in order to allow successful braze material coating. Fabricated, multi piece tubes, on the other hand, are formed from flat stock that can easily be coated with braze material first, obviating the need to coat the fins.

In the case of tubes that are subjected to a fairly high internal pressure, it has been the practice to incorporate an internal strengthening member inside the tube, to act in tension to hold the walls together. Such members also divide the tube interior into multiple, smaller passages, with the obvious improvement in heat transfer that results therefrom. Extruded tubes use simple, integral dividing and strengthening ribs, which cannot practically be made as anything but straight, uninterrupted walls. Fabricated high pressure tubes have far more potential design variations, since the internal member can be, but need not absolutely be, made as a separate piece. In addition, the outer shell or walls of the tube can and has been made in a variety of ways, which are outlined below.

The simplest design for a fabricated tube that does not need internal reinforcement for internal pressure resistance is simply a folded shell, with a live hinge on one side and a seam on the other. An example may be seen in USPN 4,470,452. Adding a corrugated web on the inside can easily be done before the tube is folded, as seen in Japanese patent 57-66389, a patent which also illustrates the equivalence between the extruded and fabricated tube design. A design that attempts to combine the advantages of fabricated and extruded designs uses a single piece of metal stock folded in a general Z shape, with the center of the Z being corrugated to provide the inner web, and the top and bottom of the Z folded down over the center corrugation from opposite directions to form integral outer walls of the tube. An example may

be seen in USPN 2,757,628. While one piece, such a design is limited insofar as both the central corrugation and top and bottom walls must have the same material and thickness, meaning that the integral internal web may well be thicker and heavier than it would otherwise have to be. In addition, the internal web will inevitably be coated with the same braze material as the outer integral walls. A variation of the Z design bends the two outer walls only half way down over the width of the tube, into abutment with a single central wall, giving only two, rather than several, divided compartments in the tube. An example is shown in USPN 4,633,056, which also shows that the edges of the outer walls, where they are brazed to the single central wall, may either be sharp, or bent over in a curved foot, the latter obviously giving more surface to surface braze contact, although requiring an extra bending step in processing.

Very early on, it was recognized that a simple, strengthened version of the hollow fabricated tube, divided into n distinct chambers, could be made with (n-1) separate pieces of metal stock by bending the separate pieces over with short 90 degree inner walls welded to one another along the surface, with edges that abut the inner surface of the tube. As such, the welded inner walls act as spacers and strengtheners for the tube as a whole. An example may be seen in UK patent 1,149,923. The simplest version of this basic design is simply two (n) chambers, with only one (n-1) piece of metal stock, bent back on itself to the center in a general B shape, with only two adjacent 90 degree inner walls, centrally located. While this simple design does not provide particularly compact flow paths, it is stronger than a single chamber, hollow tube. With the later common use of braze material coated metal stock, it was possible to eliminate the separate welding step for the abutted 90 degree edges, which would naturally braze to one another as the surface material melted, as shown in published Japanese Patent Application 63242432A. While the design shown there uses sharp edged inner walls, it is also known to provide inwardly bent feet to the otherwise sharp edges. These may be either curved feet, as taught by USPN 4,633,056 noted above, or

perpendicular and flattened feet, as shown in USPN 6,004,461. Compared to sharp edges, the integral, outwardly bent feet provide more surface in mutual contact between the central stiffening walls and the opposed inner surface of the tube.

It is also known to incorporate an integral corrugation within the basic B tube design, analogous to the integral corrugation in the simple folded tube of USPN 2,757,628. An example may be seen in USPN 5,441,106, in which the inwardly bent curved feet described above are, in effect, extended on out to create two halves of an internal web. Such a design has the same basic drawbacks as the integral corrugation design shown in USPN 2,757,628, in that the inner web and outer walls must be of the same thickness and material, and will be inevitably coated with braze material, as well. A common feature of internal corrugated webs in all fabricated tubes, so far as is known, is that the corrugations are regular or symmetric. This gives both a uniform size for all of the flow paths (but for the outboard pair, which are often inevitably smaller in cross section), and gives a uniform internal pressure resistance to the tube all across its width.

SUMMARY OF THE INVENTION

The invention is a novel tube construction that has the central strengthening feature of the B tube design described above, but with divided flow paths provided by a specially designed, separate inner corrugated web.

In the preferred embodiment disclosed, the outer shell of the tube is formed in a general "B" shape, with two 90 degree walls that abut at the center. Preferably, the edges of the abutting 90 degree walls are curved upwardly, rather than being sharp. Unlike other fabricated tubes, however, the edges of the 90 degree walls do not directly contact the inner surface of the tube. Instead, a corrugated inner web is placed inside the tube as it is folded down, and is captured between the under surface of the 90 degree wall edges and the opposed inner surface of the tube. The corrugated web, rather than

being regular and symmetric, has a widened and flattened central channel that allows it to be captured without deforming the corrugations to either side. Preferably, both the inner and outer surfaces of the outer tube are braze coated, so that the inner web need not be.

In the braze operation, one side of the web channel brazes to the undersurface of the 90 degree wall edges, and the other side of the web channel brazes to the opposed inner surface of the tube, solidly anchoring and locating the web within the tube. The net effect is that the abutted 90 degree walls strengthen the tube, even without direct contact across both sides of the tube. The web can be formed with any desired thickness, independent of the outer tube wall thickness and, as noted, need not be braze coated, though it can be. Small, divided flow paths inside the tube are created both by the regular corrugations located to either side of the central web channel, and by the location of the abutted 90 degree walls within the central web channel. The decoupling of the web and tube material allows the optimal material to be independently used for both, but the end result is similar to a one piece extruded tube in terms of strength and function.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features of the invention will appear from the following written description, and from the drawings, in which:

Figure 1 is a perspective view of the end of a preferred embodiment of a tube made according to the invention;

Figure 2 is an end view of a piece of tube stock prior to the manufacturing operation;

Figure 3 is an end view of the tube stock after a first bending operation;

Figure 4 is an end view of the tube stock after a second bending operation;

Figure 5 is an end view of the tube stock after a third bending operation;

Figure 6 is an end view of the tube stock after a fourth bending operation, and showing the web;

Figure 7 is an end view of the tube stock after a fifth bending operation, and showing the web in place;

Figure 8 is an end view of the tube stock after a sixth bending operation, and showing the web in place and anchored down.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to Figure1, an end view of a preferred embodiment of a tube according to the invention, indicated generally at 10. Tube 10 is a brazed, fabricated tube, having only two basic components, one of which is an outer shell formed with two inner chambers, like the so called "B tube" configuration described in UK patent 1,149,923 noted above. As such, n=2 (the number of inner chambers), and only n-1, or one, piece of tube stock is needed to form the outer shell, in a manner described in more detail below. Specifically, the outer shell, though unitary, can be conceptualized as a single, full width lower wall 12 spaced from a pair of upper walls 14 which preferably, but not necessarily, are equal in width. Upper walls 14 are integral to a pair of equal height, abutted 90 degree walls 16, each of which terminates in a curved, out turned foot 18. The abutted 90 degree walls 16 form a central seam running the entire length of the outer shell of tube 10, and form a central strengthening member therefor. While the coincidental provision of two divided chambers within tube 10 would provide some heat transfer advantage, by the obvious expedient of providing a greater ratio of conductive perimeter surface per enclosed volume, that effect is minimal, for such a minimal subdivision of the inner volume. The primary advantage of the abutted 90 degree walls 16, as in the UK patent noted above,

is simply the additional stiffening and strengthening and outer shell, and the location of the inevitable at least one seam down the central upper surface of the tube 10, rather than down the side edge. The end of tube 10 is ultimately brazed into a header slot, as with any headered cross flow heat exchanger, and it is easier to control the geometry of the slot-tube end braze interface along the width of the slot, rather than at the edge of the slot.

Referring next to Figures 1 and 5, the other basic component of tube 10 is a corrugated inner web, a preferred embodiment of which is indicated generally at 20. Web 20 would likely be same basic material as the outer shell of tube 10, or at least similar enough to prevent a significant galvanic differential. However, web 20 need not be identical to the outer shell of tube 10, since it is not integral therewith. Therefore, it can be, preferably, thinner, as shown, and need not be coated with braze material on its outer surface (though it can be, as described in more detail below). Specifically, web 20 has a width W1 and is formed with a series of corrugations 22 which may be, but need not be, generally sinusoidal and regular in shape, with rounded crests and sloped sides. They could also be more pointed at the crests, or completely squared off with vertical sides, if desired. Most significantly, the entire width of web 20 is not comprised of regular, symmetrical corrugations, as is conventional. Instead, a widened, intermediate channel 24 of width C, is formed, which is flattened at the bottom, and open at the top, for a purpose described below. Preferably, the channel 24 is also central to the web 20, with an equal number of regular corrugations 22 located to either side, though, again, it need not absolutely be centrally located.

Referring next to Figures 2 through 5, the initial steps in the manufacture of the outer shell of tube 10 are illustrated. A single, flat piece of flat metal stock S is braze coated on at least one surface, that which will ultimately comprise the outer surface of tube 10 and, preferably, on the other surface, as well, though not necessarily on more than the outer surface. Most likely, stock S would be pulled from a continuous coil of stock, and run through a progressive series of rollers, that would continually and gradually

form it into the subsequent shapes illustrated, rather than being bent incrementally in individual dies. The first step in the gradual formation of the final shell shape is the bending of the curved feet 18, each of which has a total width F, shown in Figure 3. Next, as shown in Figure 4, the 90 degree walls 16 are bent to shape, each with a total height H, which will ultimately determine the inner height of final tube 10. The two upper walls 14 are partially bent up, leaving the lower wall 12 in the center. As disclosed, each upper wall 14 is preferably one half the total outside width W2 of lower wall 12, "upper" and "lower" being terms of convenience, of course. Before the upper walls 14 are bent too close together to prevent it, web 20 would be fed in between them by a suitable apparatus.

Referring next to Figures 6 through 8, after the web 20 is fed in, the upper walls 14 are bent progressively farther over and, eventually, the web 20 settles onto the inner surface of lower wall 12. The web width W1 is comparable to the width W2 of lower wall 12, less by approximately twice the wall thickness of stock S, so as to facilitate the location of web 20 inside of tube 10. Eventually, the upper walls 14 are bent over far enough to abut, and the under surfaces of the feet 18 pass by the crests of the two inner most corrugations 22 and down to engage the upper surface of web channel 24, anchoring its lower surface to the inner surface of lower wall 12. The height H of the 90 degree walls 16, added to the thickness of the material of web 20, is set so as to assure that the tops and bottoms of the web corrugations 22 make close contact, without crushing, with the inner surfaces of both the upper walls 14 and the lower wall 12. The total width of the out turned feet 18 is just slightly less than the width C of web channel 24, so as to assure a close fit into the channel 24 without binding, but still serving to help positively locate the web 20 accurately within the interior of tube 10, with a limited side to side play.

Referring finally to Figures 1 and 8, the fully nested and abutted composite of the bent metal stock S and separate, anchored inner web 20 are brazed together in a conventional braze oven to complete tube 10. This

is best done as part of an entire core with tubes 10. As is typical, braze material melted from and near the interfaces of the abutted component surfaces is drawn by capillary action into those closely abutted interfaces, later hardening to create strong bonds. There are several possible combinations for the braze coating of these contacting surfaces. Both surfaces of the tube stock S could be coated, and web 20 not at all. Or, only the outer surface of the tube stock S could be coated, and both sides of the web 20 coated. When a total core is brazed, clad material on the air centers could provide what was needed for a bolted walls 16, so bare tube stock S could be used. Or, all surfaces could be coated, on both. Any such combination would provide a supply of melted braze material to the various interfaces. For example, the under surfaces of the feet 18 would braze to the upper surface of the flattened channel 24, and the under surface of channel 24 would braze to the inner surface of tube lower wall 12, ultimately securing the upper walls 14 to the lower wall 12. The abutted 90 degree walls alone 16 add a degree of strengthening to the tube 10, and the presence of the intermediate bonded corrugations add to that strengthening, depending on the thickness of the material of web 20. That thickness cannot be varied in the design shown in USPN 5,441,106, where the thickness of outer shell and inner web are inevitably the same. One of the advantages of decoupling the outer shell from the inner web is that, for example, a very thin web 20 could be used in a low pressure tube, where additional strength was not needed. Another advantage is the ability to not coat the web 20 with the rather abrasive braze material that tends to wear on the machines that typically produce corrugations like 22. Regardless of the thickness and consequent inner pressure resistance potential of web 20, it serves to subdivide the interior of tube 10 into multiple flow paths, with the attendant increase in the ratio of conductive surface area (wetted perimeter) to flow area that improves efficiency. The location of the abutted 90 degree walls, within the web channel 24, serves to produce two subdivided flow channels, in and of itself.

Variations of the preferred embodiment disclosed could be made. The width F of the curved feet 18 could be varied, in absolute terms, but making the width of the feet 18 together approximately equal to the width of two corrugations 22 serves to subdivide the channel 24 into two flow paths approximately equal to the size of the flow paths created by each of the corrugations 22, and so yields a measure of structural symmetry across the entire width of tube 10. The degree of curvature of the feet 18 could be made more or less, but flattened edges, or sharp edges, instead of a curvature would not be preferred. Such edges would not braze as well to the upper surface of the channel 24, and would not be as likely to fold past the adjacent web corrugations 22 without binding as the upper walls 14 were folded down. As disclosed, the abutted 90 degree walls are central, and the upper walls 12 consequently of equal width, but they could be shifted to one side or the other, if desired, especially if the relative width of the feet 18 and the corrugations 22 noted above were maintained, since the effect on the inner structural symmetry of the tube 10 would not be severe. Therefore, it will be understood that it is not intended to limit the invention to just the embodiment disclosed.